# Diesel Exhaust, Solvents, and Other Occupational Exposures as Risk Factors for Wheeze among Farmers

**Jane A. Hoppin, David M. Umbach, Stephanie J. London, Michael C. R. Alavanja, and Dale P. Sandler**

Epidemiology Branch and Biostatistics Branch, National Institute of Environmental Health Sciences, National Institutes of Health, Department of Health and Human Services, Research Triangle Park, North Carolina; Occupational Epidemiology Branch, National Cancer Institute, National Institutes of Health, Department of Health and Human Services, Rockville, Maryland

**Farmers engage in activities that result in exposure to diesel exhaust, solvents, welding fumes, and other respiratory irritants. Using the Agricultural Health Study, a cohort of pesticide applicators in Iowa and North Carolina, we evaluated the odds of wheeze associated with nonpesticide occupational exposures. We used logistic regression models controlling for age, state, smoking, and history of asthma or atopy to evaluate odds of wheeze in the past year among the 20,898 farmers who provided complete information on all covariates. Driving diesel tractors was associated with elevated odds of wheeze (odds ratio = 1.31; 95% confidence interval = 1.13, 1.52); the odds ratio for driving gasoline tractors was 1.11 (95% confidence interval = 1.02, 1.21). A duration–response relationship was observed for driving diesel tractors but not for driving gasoline tractors. Activities involving solvent exposure, including painting and use of solvents for cleaning, were associated with an increased odds of wheeze in a duration-dependent fashion. The highest odds of wheeze for farm activities were for daily painting (odds ratio = 1.82; 95% confidence interval = 0.89, 3.73), an indication of daily solvent exposure. These results add to the growing body of evidence of adverse respiratory effects of diesel exposure on the lung and suggest exposure to solvents may contribute as well.**

**Keywords:** agriculture; diesel exhaust; occupational cohort; respiratory symptoms; solvents

Farmers have higher rates of asthma and respiratory symptoms than do other workers (1–6). Although most of these respiratory effects have been attributed to animal and grain exposures, farmers are also exposed to a wide array of industrial toxicants because of their farm activities. Crop production, equipment repair, maintenance, and transportation represent the bulk of a farmer's daily tasks (1, 7, 8). Exposures associated with these tasks include dusts, welding fumes, diesel and gasoline exhaust, solvents, and other common industrial exposures that may contribute to respiratory symptoms. The American Thoracic Society document on respiratory health hazards in agriculture (1) identified the need to characterize these exposures regarding their impact on the respiratory health of agricultural workers. To explore the impact of these occupational activities on respiratory symptoms of farmers, we assessed the odds of wheeze among farmers in the Agricultural Health Study (AHS), a cohort representing diverse farming activities in Iowa and North Carolina. We have previously evaluated the associations between wheeze and occupational exposures to pesticides and farm animals in this cohort (9, 10). Some of the results presented here have been previously reported in abstract form (11).

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Correspondence and requests for reprints should be addressed to Jane A. Hoppin, Sc.D., NIEHS, Epidemiology Branch, MD A3-05, P.O. Box 12233, Research Triangle Park, NC 27709-2233. E-mail: hoppin1@niehs.nih.gov

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## METHODS

We conducted this cross-sectional analysis of occupational farming exposures and wheeze among farmers in the AHS (12). Approximately 52,000 farmers enrolled by completing a questionnaire at pesticide certification; 22,916 participants (44%) returned a more detailed questionnaire, which included questions regarding wheeze and asthma history. Applicators who did or did not return the second questionnaire were similar with regard to demographics, farming practices, and asthma (13). This analysis was limited to those who returned both questionnaires. The AHS has been approved by institutional review boards at the National Institutes of Health (Bethesda, MD), University of Iowa (Iowa City, IA), and Battelle Life Sciences (Columbus, OH).

From the two questionnaires, we obtained information on smoking history, demographics, and information regarding wheeze and doctor diagnosis of asthma, eczema, or hay fever, and detailed information regarding frequency of common farm tasks, types of tractors used, farm maintenance activities, as well as types of solvents used. The outcome, wheeze in the past year, was based on the question: "How many episodes of wheezing or whistling in your chest have you had in the past 12 months?" Any positive response was included in the wheeze group. Atopy history was defined as a self-report of a doctor diagnosis of either eczema or hay fever.

We evaluated occupational farming exposures as risk factors for wheeze using a common logistic regression model controlling for age in 10-year categories, state, smoking history (current, past, never), history of asthma and atopy (four levels: asthma and atopy, asthma only, atopy only, and neither), and an interaction term between current smoking and asthma. Our analysis focused on whether current farming activities contributed to wheezing among farmers. Because both asthma and atopy influenced wheeze independent of exposure, these variables were included in the base model. We included interaction terms in our models to assess whether odds of wheeze associated with exposure differed for asthmatic or atopic individuals. We evaluated farm activities using both ever/never responses and ordinal frequency variables. For solvents, we evaluated gasoline and other solvents separately and created a combined variable based on the frequency of any solvent exposure. High exposure was defined as daily use of either gasoline or other solvents or weekly exposure to both gasoline and other solvents; medium solvent exposure was defined as weekly exposure to gasoline or other solvents; low exposure was defined as monthly exposure to at least one solvent. $\chi^2$ tests for trend were performed using the questionnaire frequency categories or the exposure level for the derived solvent variable (none, low, medium, high). Because related factors may contribute to wheeze among farmers, we conducted secondary analyses by including multiple exposures in the same model to assess potential confounding by correlated farming exposures. We evaluated whether history of atopy and/or asthma influenced response to exposure by adding terms for two-way interactions with exposure (e.g., atopy $\times$ exposure) and using likelihood ratio tests. We evaluated whether smoking history influenced response to exposure by including two interaction terms (current smoking $\times$ exposure, past smoking $\times$ exposure). All statistical analysis was conducted using SAS release 8.02 (SAS, Cary, NC).

## RESULTS

A total of 20,898 farmers had complete information on all base model covariates. Respondents were predominantly white males;

they ranged in age from 16 to 88 years at the time of enrollment (Table 1). Nineteen percent reported at least one episode of wheeze in the year before enrollment, whereas only 5% of the cohort reported a history of asthma. Among the 3,922 individuals reporting wheeze, 61% reported 1 or 2 episodes in the past year, 16% reported 3–6 episodes, 7% reported 7–12 episodes, and 16% reported more than 12 episodes in the past year. Individuals with asthma represented 9, 20, 32, and 42% of each wheeze category, respectively. A majority of participants held a job off the farm at some point during their lifetime; these individuals were more likely to report wheezing in the past year than those who did not have a job off the farm.

Among crop-related activities, hand-picking crops had the highest odds of wheeze (Table 2). Hand-picking of crops was associated with lower odds of wheeze among individuals with asthma (odds ratio [OR] = 0.90; 95% confidence interval [95% CI] = 0.67, 1.21; $p_{interaction} = 0.03$) but increased odds of wheeze among nonasthmatic individuals (OR = 1.25; 95% CI = 1.14, 1.39). Use of natural fertilizer had elevated odds of wheeze, with a significant trend of increasing odds of wheeze with increasing frequency of exposure (Table 3). When natural and chemical fertilizer use was included in the same model, the OR for natural fertilizer remained elevated but the OR for chemical fertilizer did not. Individuals with atopic asthma had higher odds of wheeze associated with use of natural fertilizer (OR = 1.45; 95% CI = 1.18, 1.78) than did those with nonatopic asthma (OR = 1.10. 95% CI = 1.01, 1.21; $p_{interaction} = 0.02$).

Driving diesel tractors and driving trucks on the farm were associated with elevated odds of wheeze ($OR_{diesel} = 1.31$; 95% CI = 1.13, 1.52; $OR_{trucks} = 1.20$; 95% CI = 1.10, 1.31) and with significant duration–response trends. Driving diesel tractors daily was associated with an odds ratio of 1.38 (95% CI = 1.17, 1.61). No trend was observed with increasing frequency of driving gasoline tractors (Table 3). When both diesel tractors and gasoline tractors were included in the same model, the elevated OR for ever driving diesel tractors was unchanged, but the OR for gasoline tractors was attenuated to 1.08 (95% CI = 0.99, 1.16). In models stratified by reported frequency of wheeze, we observed elevated odds ratios for daily diesel tractor driving for the 1 or 2 episodes/year group (OR = 1.36; 95% CI = 1.12, 1.65), 3–6 episodes/year group (OR = 1.19; 95% CI = 0.85, 1.67), 7–12 episodes/year group (OR = 1.26; 95% CI = 0.77, 2.08), and the greater than 12 episodes/year group (OR = 1.59; 95% CI = 1.08, 2.33). No interaction was observed with history of asthma. In analyses stratified by smoking status, never-smokers had the highest odds of wheeze associated with driving diesel tractors (OR = 1.58; 95% CI = 1.31, 1.91), with current smokers (OR = 1.27; 95% CI = 0.94, 1.74) and past smokers (OR = 1.08; 95% CI = 0.87, 1.34) having elevated but not significantly increased odds of wheeze ($p_{interaction} = 0.02$). Individuals with asthma were more sensitive to driving gasoline tractors (OR = 1.45; 95% CI = 1.08, 1.94; $p_{interaction} = 0.06$), than nonasthmatic individuals (OR = 1.08; 95% CI = 0.99, 1.20).

Activities involving solvent exposure, including painting and use of solvents for cleaning, were associated with increased odds of wheeze in a duration-dependent fashion (Table 3). The highest odds of wheeze for all farm activities evaluated were associated with using solvents daily. All metrics of daily solvent exposure were associated with elevated odds of wheeze: painting (OR = 1.82; 95% CI = 0.89, 3.73), cleaning with gasoline (OR = 1.43; 95% CI = 0.85, 2.41), and cleaning with other solvents (OR = 1.63; 95% CI = 1.09, 2.43). When we combined use of gasoline and other solvents, individuals reporting a high frequency of use of either solvent had an odds ratio of 1.71 (95% CI = 1.33, 2.20). When use of solvents as pesticide additives was included in the model with ever-use of gasoline and ever-use of other solvents, the elevation in odds ratios persisted for all solvent variables. The impact of solvent exposure did not differ by smoking status. Among individuals with atopy, wheeze was more strongly associated with using gasoline as a solvent (OR = 1.55; 95% CI = 1.25, 1.93; $p_{interaction} = 0.07$) than among nonatopic individuals (OR = 1.27; 95% CI = 1.15, 1.39).

Repair and maintenance activities were associated with increased odds of wheeze, particularly among respondents reporting replacing asbestos brakes (OR = 1.22; 95% CI = 1.10, 1.34) and repairing pesticide equipment (OR = 1.25; 95% CI = 1.15, 1.35). No frequency information was collected for these activities.

Because of the large number of correlated respiratory toxicants that farmers experience on a regular basis, we constructed models containing other predictors of respiratory symptoms, including pesticides, animals, and solvents. The impact of these additional factors on the odds ratio estimates was minimal for all exposures evaluated. The frequency of diesel tractor use was correlated with farm size, but the addition of farm size to the model with diesel tractor use resulted in an increased odds ratio for diesel tractors (1.51 versus 1.38). We continued to observe a significant duration–response trend with frequency of diesel tractor driving after the addition of other farm-related exposures into the model (e.g., pesticides, solvents, animals, natural fertilizer, and farm tasks). The largest attenuation of the diesel odds ratio estimates was 3.2% and occurred when raising farm animals was included in the model for ever-driving diesel tractors; the odds ratios for the duration–response models changed less than 1%. The odds ratio for driving diesel tractors changed from 1.31 to 1.27 when raising animals was included in the model. No

**TABLE 1. DEMOGRAPHIC, FARM, AND MEDICAL CHARACTERISTICS OF THE 20,898 FARMERS IN THE AGRICULTURAL HEALTH STUDY BY WHEEZE STATUS, 1993–1997**

| | Wheeze (*n = 3,922*) | No Wheeze (*n = 16,976*) |
|---|---|---|
| Age, yr | | |
| Mean (SD) | 48 (13.3) | 49 (13.0) |
| Median (minimum, maximum) | 47 (16, 88) | 48 (16, 88) |
| Race, n (%)* | | |
| White | 3,831 (98) | 16,538 (98) |
| Other | 82 (2) | 391 (2) |
| Sex, n (%) | | |
| Female | 90 (2) | 414 (2) |
| Male | 3,832 (98) | 16,562 (98) |
| State, n (%) | | |
| Iowa | 2,459 (63) | 11,656 (69) |
| North Carolina | 1,463 (37) | 5,320 (31) |
| Education level, n (%)* | | |
| < High school | 368 (10) | 1,394 (8) |
| Completed high school | 1,858 (49) | 7,978 (48) |
| > High school | 1,604 (42) | 7,261 (44) |
| Job off the farm | 2,672 (69) | 10,872 (65) |
| Smoking status, n (%) | | |
| Never | 1,711 (44) | 9,688 (57) |
| Past | 1,284 (33) | 5,502 (32) |
| Current | 927 (24) | 1,786 (11) |
| Asthma–atopy status, n (%)† | | |
| Neither | 2,725 (69) | 15,171 (89) |
| Asthma only | 373 (10) | 240 (1) |
| Atopy only | 509 (13) | 1,435 (9) |
| Asthma and atopy | 315 (8) | 130 (1) |

*Definition of abbreviation*: SD = standard deviation.

* Race and education variables do not sum to total sample size because of missing data.

† Atopy defined as self-report of hay fever or eczema.

**TABLE 2. ODDS RATIOS FOR WHEEZE IN THE PAST YEAR AND COMMON FARM ACTIVITIES AMONG FARMERS IN THE AGRICULTURAL HEALTH STUDY, 1993–1997**

| Farm Activity | Wheeze: n = 3,922 (%) | No Wheeze: n = 16,976 (%) | Odds Ratio* | 95% Confidence Interval | p Trend† |
|---|---|---|---|---|---|
| Crop activities | | | | | |
| Till soil | 94 | 94 | 1.14 | 0.97, 1.34 | 0.0007 |
| Drive combines | 79 | 80 | 1.13 | 1.02, 1.26 | 0.0056 |
| Plant | 90 | 91 | 1.03 | 0.91, 1.18 | 0.3105 |
| Use natural fertilizer | 65 | 65 | 1.15 | 1.06, 1.25 | < 0.0001 |
| Use chemical fertilizer | 82 | 81 | 1.04 | 0.94, 1.14 | 0.0679 |
| Hand pick | 37 | 30 | 1.24 | 1.13, 1.35 | 0.014 |
| Farm transportation | | | | | |
| Drive trucks | 69 | 63 | 1.20 | 1.10, 1.31 | 0.0023 |
| Diesel tractors | 87 | 86 | 1.31 | 1.13, 1.52 | 0.0002 |
| Gas tractors | 59 | 58 | 1.11 | 1.02, 1.21 | 0.44 |
| Maintenance activities | | | | | |
| Weld | 57 | 57 | 1.10 | 1.01, 1.19 | 0.027 |
| Repair engines | 36 | 32 | 1.19 | 1.11, 1.29 | 0.0009 |
| Grind metal | 60 | 58 | 1.20 | 1.10, 1.30 | 0.001 |
| Replace asbestos brakes | 18 | 15 | 1.22 | 1.10, 1.34 | NA‡ |
| Repair pesticide equipment | 69 | 64 | 1.25 | 1.15, 1.35 | NA |
| Solvent exposures | | | | | |
| Paint | 21 | 18 | 1.20 | 1.11, 1.29 | < 0.0001 |
| Gasoline to clean | 29 | 24 | 1.33 | 1.23, 1.43 | < 0.0001 |
| Other solvents to clean§ | 21 | 18 | 1.16 | 1.09, 1.28 | < 0.0001 |

* Odds ratios adjusted for age, state, smoking, asthma, atopy, asthma × atopy, and current smoking × asthma.
† $\chi^2$ test for trend based on questionnaire categories (from three to five levels).
‡ NA = not applicable. Frequency information was not collected.
§ Defined as "other solvents (like paint stripper, turpentine, benzene)."

changes were observed in the odds ratio estimates for solvent and paint exposure. Because of the low level of confounding by these additional variables, they were not included in the final models.

## DISCUSSION

Farming is among the occupations most frequently associated with respiratory morbidity (1). Animals, grains, dusts, and, to a lesser extent, pesticides have been the potential risk factors explored by researchers to date. In addition to farmers, painters, carpenters, welders, metal workers, mechanics, and diesel-exposed workers have higher rates of asthma and other respiratory morbidity and mortality (4, 14–28). Farmers also engage in tasks common to these other occupational settings, and we observed that exposures related to these other occupational groups were associated with wheeze among farmers in the AHS.

Diesel exhaust exposure has been associated with adverse respiratory effects among workers, although not consistently (26, 28, 29). Gamble and colleagues observed higher rates of wheeze and other respiratory symptoms among diesel bus mechanics employed for five or more years compared with other blue collar workers (28). Bus drivers and mechanics in Croatia had a higher prevalence of respiratory symptoms compared with control subjects with higher symptom rates among workers exposed 10 years or more (29). Ulvestad and colleagues reported increased wheeze among diesel-exposed tunnel workers compared with outdoor heavy construction workers (26). In our analysis, driving diesel tractors was a consistent and robust predictor of wheeze among farmers in the AHS cohort, whereas driving gasoline tractors was not.

Diesel exhaust is a complex mixture of fine particulate, nitrogen oxides, and, particularly with farm equipment, sulfur dioxide, because of the higher amounts of sulfur allowed in diesel fuel for off-road uses (30). A majority of diesel particulate emissions are ultrafine particles (< 1 μm) and thus are able to reach the bronchial and alveolar regions of the lungs (31). Diesel particulates have been demonstrated to enhance the allergenicity of other agents both in animals and in humans (31–39). Not only can diesel particles enhance allergenicity, they also act as allergen carriers (35, 36), thus making allergens more accessible to the deep lung regions. We attempted to explore the impact of diesel exhaust and allergens by evaluating the statistical interaction between diesel tractor driving and use of natural fertilizer, a source of many allergenic agents. Using this strategy, we did not find evidence of an interaction between diesel exposure and natural fertilizer use; however, given that we were able to assess potential allergen exposure only via a surrogate from the questionnaire, our data are insufficient to adequately investigate the interaction between diesel exhaust and allergens.

Painters and other occupational groups exposed to paints and solvents have been reported to have increased respiratory morbidity and mortality, although the data on the respiratory health effects of solvents are limited (4, 15, 17, 21, 22, 40, 41). Schenker and Jacobs reviewed the solvent and respiratory health effects literature in 1996 (41). They observed that although the association between solvents and respiratory symptoms and disease is biologically plausible given the animal data concerning effects on both conducting and respiratory airways, the epidemiologic evidence is limited because of poor exposure data. Since that time, other studies have evaluated the respiratory health impact of solvents and paints. Painters in some populations (22), but not all (4), have reported higher rates of bronchial hyperresponsiveness and wheezing. Paint hardeners, particularly isocyanates, have been associated with occupational asthma (15, 42, 43). Aircraft maintenance workers exposed to trichloroethylene and those exposed to other solvents had higher mortality from asthma than the general population and unexposed workers (44). Wieslander and colleagues have assessed the impact of water-based paints and solvent-based paints among house painters in

**TABLE 3. DURATION–RESPONSE MODELS FOR WHEEZE IN THE PAST YEAR AND FERTILIZER, TRACTOR, AND SOLVENT EXPOSURE AMONG FARMERS IN THE AGRICULTURAL HEALTH STUDY, 1993–1997**

| | Wheeze: n = 3,922 (%) | No Wheeze: n = 16,976 (%) | Odds Ratio* | 95% Confidence Interval |
|---|---|---|---|---|
| Fertilizer use | | | | |
| Natural fertilizer | | | | |
| Never | 35 | 35 | 1.00 | |
| 1–5 d/yr | 24 | 24 | 1.07 | 0.97, 1.18 |
| 6–25 d/yr | 25 | 25 | 1.19 | 1.07, 1.32 |
| 26–50 d/yr | 9 | 9 | 1.27 | 1.09, 1.47 |
| > 50 d/yr | 6 | 6 | 1.28 | 1.08, 1.51 |
| Chemical fertilizer | | | | |
| Never | 18 | 19 | 1.00 | |
| 1–5 d/yr | 42 | 45 | 1.00 | 0.90, 1.11 |
| 6–25 d/yr | 35 | 32 | 1.09 | 0.98, 1.21 |
| 26–50 d/yr | 4 | 3 | 1.10 | 0.89, 1.36 |
| > 50 d/yr | 1 | 0.8 | 1.09 | 0.74, 1.60 |
| Tractor driving | | | | |
| Diesel tractors | | | | |
| Never | 7 | 8 | 1.00 | |
| Monthly | 7 | 7 | 1.23 | 1.01, 1.50 |
| Weekly | 44 | 44 | 1.29 | 1.11, 1.51 |
| Daily | 42 | 41 | 1.38 | 1.17, 1.61 |
| Gasoline tractors | | | | |
| Never | 29 | 29 | 1.00 | |
| Monthly | 25 | 23 | 1.15 | 1.04, 1.28 |
| Weekly | 35 | 35 | 1.12 | 1.02, 1.24 |
| Daily | 11 | 12 | 0.99 | 0.86, 1.13 |
| Solvents | | | | |
| Paint | | | | |
| Never | 58 | 61 | 1.00 | |
| Monthly | 40 | 37 | 1.18 | 1.09, 1.28 |
| Weekly | 3 | 2 | 1.41 | 1.10, 1.81 |
| Daily | 0.3 | 0.2 | 1.82 | 0.89, 3.73 |
| Gasoline to clean | | | | |
| Never | 57 | 63 | 1.00 | |
| Monthly | 36 | 31 | 1.32 | 1.21, 1.43 |
| Weekly | 7 | 6 | 1.39 | 1.20, 1.61 |
| Daily | 0.6 | 0.4 | 1.43 | 0.85, 2.41 |
| Other solvents to clean | | | | |
| Never | 71 | 75 | 1.00 | |
| Monthly | 23 | 21 | 1.14 | 1.04, 1.24 |
| Weekly | 4 | 3 | 1.39 | 1.15, 1.68 |
| Daily | 1.0 | 0.6 | 1.63 | 1.09, 2.43 |
| Both gasoline and solvents to clean† | | | | |
| Never | 46 | 51 | 1.00 | |
| Low | 43 | 39 | 1.26 | 1.16, 1.36 |
| Medium | 9 | 8 | 1.37 | 1.19, 1.57 |
| High | 3 | 2 | 1.71 | 1.33, 2.20 |

* Odds ratios adjusted for age, state, smoking, asthma, atopy, asthma × atopy, and current smoking × asthma.

† Intensity based on frequency of gasoline and solvent use (low = monthly for one or both; medium = at least weekly for one; high = daily for at least one, or weekly for both).

Sweden (45). The authors observed less airway irritation among painters using water-based paints exclusively, but indicated that both types of paints contributed to volatile organic chemical exposure and that self-selection as to chemicals used was occurring. In an analysis of work-related wheezing and occupational asthma among U.S. workers, Arif and colleagues identified a higher prevalence of work-related wheezing associated with equipment cleaners, an occupational group likely to be exposed to solvents and other degreasing agents (46). In our sample we have limited information regarding the type of paint or solvent used and the types of processes used, and thus we are restricted in our ability to identify potential etiologic agents. Both using gasoline and using other solvents were associated with increased odds of wheeze in a duration-dependent manner. Use of solvents as pesticide additives was independently associated with increased odds of wheeze (9).

Farmers are generally healthier and smoke less than the general population (47), and yet they have higher rates of respiratory symptoms (1). Because particular exposures on farms may trigger respiratory symptoms, farmers may change their behaviors to prevent respiratory responses. Danish pig farmers (48) and grain processing workers (49) with respiratory symptoms were more likely to leave the industry than those without symptoms. Finnish farmers with farmer's lung and chronic bronchitis reported decreasing or eliminating their farm activities more often than other farmers (50). In a metaanalysis of longitudinal occupational studies of lung function, Radon and coworkers observed that individuals with chronic bronchitis at enrollment were more likely to leave their occupational cohort than were other members and, thus, estimates for respiratory disease and symptoms may be underestimated (51). Our cross-sectional analyses may be influenced by behavioral changes in response to exposure;

however, we have limited data to assess whether our results are influenced by the healthy worker effect. We observed higher odds of wheeze among farmers with asthma driving gasoline tractors, which may be due to less diesel tractor driving among sensitive individuals with asthma, because tractor use is a critical component of farming. Although individuals with asthma have higher rates of wheeze, when we excluded them from the analysis we continued to observe the same pattern of elevated odds ratios for farm exposures. Among farmers with atopic asthma, there was no evidence of exposure avoidance when working with natural fertilizer or gasoline as a solvent as both interactions suggested increased wheeze among individuals with atopic asthma.

Wheeze is just one of a constellation of common respiratory symptoms, including cough, phlegm, and shortness of breath. Wheeze is a common and characteristic symptom of asthma, associated with reversible bronchoconstriction. We used one question on wheeze to assign outcome; we did not collect information on other respiratory symptoms in the past year. We chose to collapse the episodes of wheeze into one variable to generate results comparable to others in the literature. Self-administered questionnaires have been demonstrated to be reliable and reproducible regarding respiratory symptoms, particularly wheeze, and doctor diagnosis of asthma (52, 53). Most other large studies of occupational groups have been conducted in a similar manner (17, 45, 54); however, these studies, unlike the AHS, were primarily focused on respiratory symptoms and have more detailed information regarding symptom severity and medication use. Farmers have been demonstrated to provide good information regarding their occupational history, particularly use of pesticides (55). Among AHS participants, good reproducibility and reliability of the self-reported information have been described (56, 57). Compared with other respiratory studies of farmers or mixed occupational groups, our study was much larger, had much more detailed information regarding a wide variety of exposures, and, consequently, provided the ability to make comparisons across heterogeneous exposures.

Our cross-sectional analysis addressed occupational exposures among farmers that have frequently been overlooked. Because a number of agents on farms may contribute to respiratory symptoms, we attempted to control for these in our analysis by including all potential agents (pesticides, animals, solvents) in our models. Addition of these variables did not the alter odds ratio estimates. However, given that this analysis relied on cross-sectional data, we have no information regarding the temporal sequence between exposure and wheeze. We do know that exposure and wheeze occurred within the same year. Other analyses have considered work-related symptoms (45, 54); however, because farmers frequently live where they work, this distinction may not be relevant for farmers.

The Agricultural Health Study provides a unique opportunity to explore the agricultural factors that may contribute to respiratory morbidity among farmers. In the current analysis, we were able to explore the association with wheeze not only of routine agricultural tasks, such as tractor driving, but also of common occupational activities, such as painting and welding. Because of the large sample size we were able to discriminate between common tasks, such as driving diesel versus gasoline tractors. The dose response with driving diesel but not gasoline tractors, and the fact that the association with diesel tractors remained after controlling for driving gasoline tractors but not the converse, supports a role for diesel exhaust exposure rather than some exposure common to both types of tractor driving, such as dust exposure. However, among farmers with asthma, driving gasoline tractors was also associated with increased risk of wheeze, which could be due to gasoline exhaust, per se, or to increased susceptibility to other factors associated with driving tractors. Similarly, the observed risk for use of natural fertilizer, but not of chemical fertilizer, suggests that some aspect of natural fertilizer, such as allergens or endotoxins, that is not present in chemical fertilizer may contribute to wheeze risk. Although wheeze is a common respiratory symptom and there is a literature to support the independent predictors identified in this cross-sectional analysis, there may be some underlying factor among farmers who wheeze that may explain our results. Longitudinal analyses will allow better resolution of the risk factors for respiratory health effects among farmers.

Farmers are exposed to a wide array of potential respiratory toxicants during their farming activities. In this analysis we focused on common occupational exposures frequently overlooked in respiratory disease studies of farmers. Further evaluation of common occupational farming exposures may allow integration of the respiratory morbidity results of studies across regions with different farm products. As diesel tractors are a major component of most farming activities, further investigation of the respiratory health risks is warranted.

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